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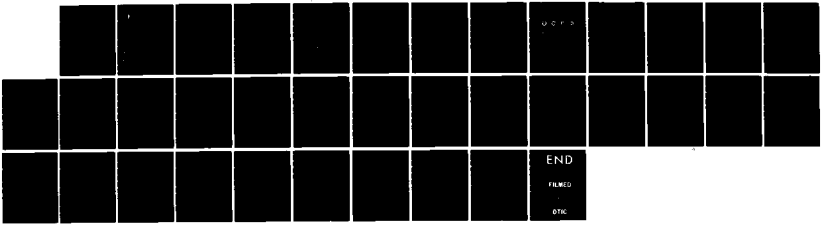

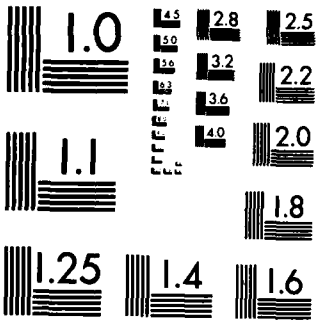

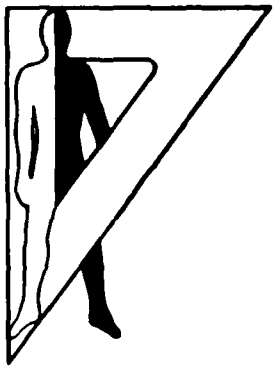

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Technical Note 2-85

MODIFIED LANDOLT C-RING TEST TO MEASURE THE EFFECTS OF LASER FILTERS ON VISUAL ACUITY

Orest Zubal

January 1985

U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The utility of the modified Landolt C-ring test in predicting gunner performance when optical (laser) filters were incorporated in the gunners' aiming/tracking sights was examined. Sixty-four qualified TOW and tank gunners participated in a quasi-tactical exercise during which they had to locate, identify, and simulate firing at targets using their respective sights. Sixty-three of the gunners were used to measure variations in their visual acuity caused by the filters which were being used in the tactical scenarios.

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CONTENTS

MODIFIED LANDOLT C-RING TEST TO MEASURE THE EFFECTS OF LASER FILTERS ON VISUAL ACUITY

INTRODUCTION

Lasers are being incorporated into modern military equipment. They are being used in gunnery training, guiding weapons, determining range, and may eventually be used as weapons. With the increasing use of laser devices, there is a concern for personnel safety. Providing eye protection for soldiers is vital especially when the soldier is using magnifying direct-view devices. Questions are also raised about what the effects on user performance will be if the direct viewing and aiming (DVA) systems had devices which would provide eye protection for the user. Whether soldiers' target engagement performance would be degraded by including elements with some optical density in the DVA devices was the focus of this study.

The USA Armor and Engineer Board at Fort Knox, KY agreed to conduct a test for the USA Human Engineering Laboratory (USAHEL) to determine the effects of incorporating laser protective filters into tank and TOW (tube-launched, optically tracked, wire-guided) sight optics. The objective of the Fort Knox test was to answer the question: "Will gunners still be able to detect, identify, and fire at targets if filters are incorporated in their sight systems?"

The Fort Knox test was divided into two phases. The first phase consisted of laboratory tests: The Farnsworth Munsel 100-hue Test, The Arden Contrast Sensitivity Test, and The Anomaloscope Test, which were administered and evaluated by the Letterman Army Institute for Research (LAIR) to measure the subjects' visual performance wearing goggles with and without filters. Individual visual acuity was obtained from the participant's medical records. The second phase involved the same test participants in a field exercise in which they had to locate, identify, and simulate fire against stationary targets. Those test participants who were rated as tank gunners only used the tank sights (M32 sights mounted in tanks), while TOW gunners used the TOW system. The results of the field test were published by the Armor and Engineer Board (Cook & Johnson, 1983); the results of the laboratory eye tests will be published by LAIR.

Concurrently, the USAHEL sought to develop and evaluate an intermediate test which could be used to pre-evaluate various filters under more controlled conditions than those of a field experiment, but not as sterile as laboratory conditions, before verifying findings with expensive field trials. The USAHEL constructed a modified Landolt C-ring test to evaluate the effects of filters not only on the visual acuity of the test participants, but also on soldiers' ability to perceive figures as a function of color and contrast ratio. The USAHEL modified Landolt C-ring test was administered to the test participants in the field by USAHEL personnel during, but not interfering with, the Fort Knox test. All testing was conducted during May and June of 1982.

The optical characteristics of the filters are not classified information; however, the effects they have on soldier performance are. The issue here is the utility of the modified Landolt C-ring test in assessing filter effects on visual acuity and not the actual effects. To keep this report unclassified, the filters are not identified in this report. Filter data can be obtained from the author.

OBJECTIVE

The objective of this test was to investigate the utility of a modified Landolt C-ring test in assessing the effects of selected laser filters on soldiers' visual acuity.

METHOD

Test Participants

The test participants used for this test were the same ones used in the Fort Knox test. The group consisted of 24 qualified TOW gunners and 40 qualified tank gunners. For this test, no distinction was made between a TOW and a tank gunner. Due to time and other limitations, only 63 test participants were involved in the USAHEL test. Demographic data of the test participants were gathered in the Fort Knox test and are not presented here.

Equipment

USAHEL made three sets of Landolt C-rings. Each set contained C-rings ranging in diameter from 4.58 in. (116.33 mm) to 0.29 in. (7.36 mm). The width of the painted C-ring and the gap in the C-ring were each one-fifth of the outside diameter. One set consisted of black C-rings on a white panel; the second set consisted of olive drab (OD) C-rings on a green panel; and the third set had black C-rings on an OD panel. Each C-ring was placed at least its own diameter away from the edge of the panel or from its neighbor. Figure 1 shows the white panel with its black C-rings. The USA Aeronautical Research Laboratory suggested that the luminance and chromaticity of the figures and backgrounds should be controlled and kept constant since those factors might influence target detectability. However, for this preliminary investigation, USAHEL had neither the time nor the ability to measure and control these two variables.

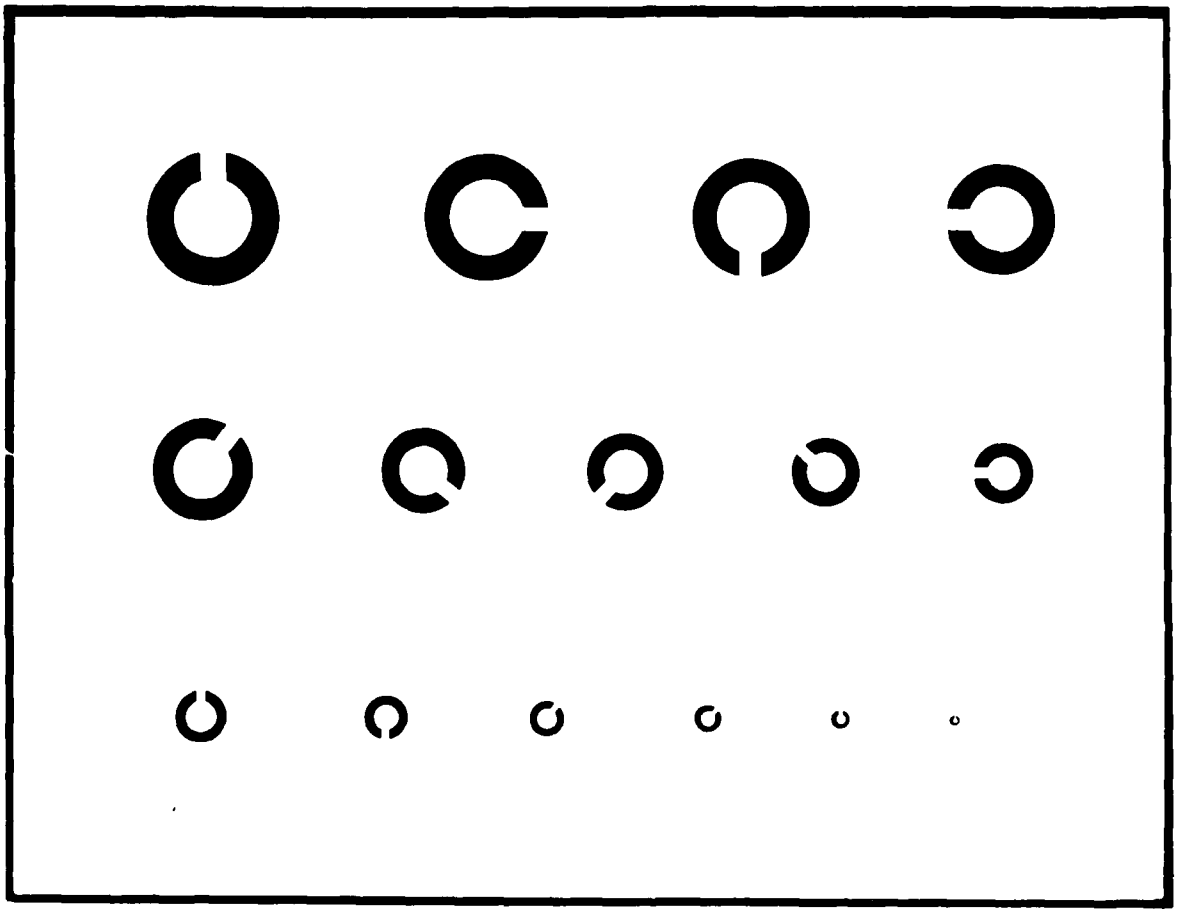


Figure 1. Typical Landolt C-ring panel used in this test.

There are many formulae which could be used to compute the contrast ratio of a figure and its background. Considering the rationales given in Barnes, 1969; Chapanis, Garner, & Morgan, 1957; Graham, 1965; and Richardson, 1968, we derived the following formula:

$$C = \frac{|\ell - L|}{B}$$

Where C = Contrast
L = Luminance of the C-ring
ℓ = Luminance of the panel
B = ℓ or L, whichever is larger

This formula was used because it uses easily obtainable data and is bounded. Other contrast formulae are unbounded, can be either positive or negative, and are more difficult to understand and interpret the calculated contrast values.

Contrast calculations were made using luminance readings taken in the field with a Pritchard telephotometer. The black-white C-ring set had a calculated contrast of 0.78, the OD-green set had a calculated contrast of 0.43, and the black-OD set had a calculated contrast of 0.23.

The panels were hung on a wooden structure erected at a viewing distance of 86.82 m. The distance was measured with a laser survey instrument for use in visual angle calculations. This distance was chosen because it was the longest uncluttered distance available in the vicinity which provided easy access to the panels for changing the C-ring orientation and quick access to the USAHEL test point for the test participants. Care was taken to ensure that the test panels and viewing device were set up the same way each day. The formula,

$$A = 87.34\ H/D$$

Where A = Visual angle, in minutes of arc
H = Gap size on C-ring, in inches
D = Viewing distance, in meters
87.34 = Combination of conversion factors for English/metric systems and for giving visual angle in minutes of arc,

was used to calculate the visual angles subtended by the C-ring gaps. This formula is for small, less than 0.125 degrees (7.5 minutes), angle approximation using the tangent function. The angles ranged from 0.92 to 0.06 minutes of arc, in increments of 0.06, at the 86.82-m viewing distance. With an eight-power viewing optic, like the M19 binoculars, the corresponding perceived angular values ranged from 7.36 to 0.48 minutes of arc, with an 0.48 increment.

A pair of M19 binoculars was modified to use as the viewing optic for this test. The left optical path, containing the reticle, was blocked. A clip-on, for holding the various circular samples of the filters one at a time, was secured on the right entrance lens. The binoculars were placed on a sturdy tripod to provide steady support during viewing. This arrangement also forced the test participants to use one eye as they would when using a tank or TOW sight. The test participants were allowed to use their preferred eye.

PROCEDURES

Standard practice, when using the Snellen eye chart, is to present several figures representing the same visual angle in a line for testing the particular visual angle. The observers then must identify a prescribed portion of the figures in a given line to indicate that they can resolve that visual angle. For expediency, we structured the test such that each C-ring represented a unique visual angle on the panel. For test participants to score a correct response, they had to circle the location of the gap of each C-ring on the data form. For our scoring purposes, incorrectly identifying the location of the gap orientation twice in a row defined a failure and the last correct response was used to define the visual acuity of each test participant.

Since the binoculars were a constant in the trials, we decided to simply use the "unaided" visual angle as the visual angle resolved by the test participants. This eliminated the necessity of determining the actual magnification of the binoculars used in this test, since the modifications may have influenced the final magnification factor of the binoculars.

The test participants were given a brief explanation of the C-ring test and were told that it was an addition to the Fort Knox test. The binoculars were shown and the participants were instructed to use the diopter adjustment to make sure that the panels and C-rings were well in focus. This point was again stressed when each participant was tested. Pure guessing was discouraged. It was pointed out that it was just as important to find out what they could not see as it was to find out what they could see. Lastly, the participants were shown how to fill out the data forms (Appendix A).

Test participants requiring corrective glasses were allowed to wear them if the glasses were not tinted. Nonprescription and prescription sunglasses were prohibited.

Ten random patterns with a unique sequence of gap orientations on each panel were developed. Each C-ring would have its gap located in one of eight positions corresponding to 12, 3, 6, and 9 o'clock points and the points halfway between these main points. All test participants viewed the same gap pattern for a given filter condition, but the pattern was changed for each filter. No one pattern was assigned to be viewed through any one particular filter. A pattern was displayed, a filter randomly chosen, and test participants were tested. The pattern was retained if testing had to be extended to the next day to complete the rotation of all the test participants for a given filter.

All testing was conducted before 1:00 P.M. to ensure that the test participants were not looking into the sun when viewing the test panels. The testing sequence was varied so that the filter and control (no filter) conditions were not always tested in the same order; similarly, the rotation of the filters was random each week. Test participants were allowed to proceed at their own pace. Most test participants worked left to right, going from white to green to OD panels. The order of observing the panels was not specified to the test participants, but they were directed to start with the largest C-ring and work down to the smallest C-ring on each panel.

RESULTS

It must be stressed that these results were obtained under very favorable conditions. Almost all test sessions were conducted on bright sunny days with minimal or no haze. No testing using the C-ring panels was done during dawn or dusk. All testing was done with the test participants looking down-sun and no stress was placed on the test participants to complete their turn in a specified time. It must also be remembered that when examining the data, the visual angles have yet to be multiplied by the final magnification factor of the binoculars (nominally 8) to obtain the final visual angle perceived by the test participants.

Table 1 shows the sample size, mean, and standard deviation (SD) for each panel and filter combination. The complete listing of all the data is shown in Appendix B, Tables 1B, 2B, and 3B.

TABLE 1

Mean Visual Angle and SD (in Minutes of Arc) As a Function of Viewing Condition and Panel Color.

Condition	White Panel			Green Panel			OD Panel		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Control	58	0.17	0.089	58	0.21	0.110	58	0.24	0.082
Filter 1	25	0.17	0.490	25	0.19	0.055	25	0.21	0.069
Filter 2	25	0.16	0.053	25	0.16	0.069	25	0.19	0.077
Filter 3	34	0.15	0.038	34	0.17	0.071	33	0.20	0.084
Filter 4	27	0.17	0.048	27	0.18	0.620	26	0.25	0.103
Filter 5	24	0.22	0.059	24	0.29	0.098	24	0.52	0.250
Filter 6	26	0.14	0.042	26	0.19	0.054	26	0.26	0.075
Filter 7	8	0.16	0.590	8	0.19	0.071	8	0.19	0.031
Filter 8	3	0.21	0.069	3	0.21	0.035	3	0.31	0.086
ALL FILTERS		0.173			0.198			0.266	

Figures 2 through 4 are histograms of the smallest visual angle perceived by the test participants for each viewing condition.

Although Table 1 presents the overall data summaries, comparisons of any sort are difficult since the sample size is not constant and does not include the same test participants. In an attempt to obtain some comparisons, we decided to include participants in the sample population for a filter condition only if they had scored six data points. The data points required were the control and filter viewing conditions obtained on all three panels. Furthermore, the control data were not combined for all test participants, but kept separate so that only the test participants for a given panel and filter condition served as their own control. The results are shown in Table 2.

TABLE 2

Matched Mean and SD Visual Angles (in Minutes of Arc) for Each Viewing Condition and Panel Color

	White Panel			Green Panel			OD Panel		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Filter 1	25	0.17	0.490	25	0.19	0.055	25	0.21	0.690
Control	25	0.20	0.114	25	0.24	0.130	25	0.28	0.080
Filter 2	18	0.18	0.046	18	0.15	0.050	18	0.18	0.053
Control	18	0.20	0.131	18	0.21	0.084	18	0.26	0.082
Filter 3	33	0.15	0.036	33	0.17	0.069	33	0.20	0.084
Control	33	0.15	0.047	33	0.22	0.088	33	0.23	0.080
Filter 4	26	0.17	0.048	26	0.17	0.059	26	0.25	0.103
Control	26	0.17	0.051	26	0.22	0.119	26	0.24	0.077
Filter 5	24	0.22	0.059	24	0.29	0.098	24	0.52	0.250
Control	24	0.17	0.058	24	0.22	0.121	24	0.25	0.077
Filter 6	26	0.14	0.042	26	0.19	0.054	26	0.26	0.075
Control	26	0.20	0.113	26	0.23	0.128	26	0.26	0.077
Filter 7	8	0.16	0.059	8	0.19	0.071	8	0.19	0.031
Control	8	0.17	0.045	8	0.19	0.062	8	0.23	0.099
Filter 8	3	0.21	0.069	3	0.21	0.035	3	0.31	0.086
Control	3	0.17	0.104	3	0.26	0.266	3	0.21	0.069

TABLE 3B

Complete Listing of Smallest Angles esolved By Test Participants
On the OD Panel for the Control and All Filter Conditions

TP	C	Filter 1	2	3	4	5	6	7	8
1	0.23	*	*	0.17	0.40	0.46	*	*	*
2	0.29	*	*	0.11	0.29	0.57	*	*	*
3	0.17	*	*	0.11	0.17	0.52	*	*	*
4	0.34	*	*	*	*	0.40	*	*	*
5	0.17	*	*	0.17	0.29	0.57	*	*	*
6	0.29	*	*	0.11	0.11	0.92	*	*	*
7	0.23	*	*	0.23	0.29	0.92	*	*	*
8	0.29	0.23	0.29	0.40	*	0.40	*	*	*
9	0.23	0.17	0.17	0.29	*	0.34	*	*	*
10	0.23	0.23	0.17	0.23	*	0.57	*	*	*
11	*	*	0.11	*	*	*	*	*	*
12	*	*	0.40	*	*	*	*	*	*
13	*	*	0.34	*	*	*	*	*	*
14	*	*	0.11	*	*	*	*	*	*
15	*	*	0.11	*	*	*	*	*	*
16	0.17	*	*	0.17	*	*	*	*	0.40
17	0.29	*	*	0.40	*	*	*	*	0.29
18	0.17	*	*	0.23	*	*	*	*	0.23
19	0.17	*	*	0.34	*	*	*	*	*
20	0.17	*	*	0.17	*	*	*	*	*
21	0.17	*	*	0.23	*	*	*	*	*
22	0.23	*	*	0.23	*	*	*	*	*
23	0.17	*	*	0.29	*	*	*	*	*
24	0.17	*	*	0.11	0.17	0.69	*	*	*
25	0.40	0.17	0.17	0.23	*	*	*	*	*
26	0.17	*	*	*	*	0.11	*	*	*
27	0.17	0.11	0.17	0.06	*	*	*	*	*
28	0.17	0.17	0.11	0.17	*	0.11	*	*	*
29	0.34	0.40	0.17	0.23	*	*	*	*	*
30	0.23	0.23	0.17	0.17	*	0.23	*	*	*
31	0.40	0.34	0.17	0.17	*	0.80	*	*	*
32	0.11	0.11	0.11	0.11	*	0.17	*	*	*
33	0.34	0.23	*	*	0.40	0.52	0.29	*	*
34	0.23	0.17	*	*	0.52	0.92	0.34	*	*
35	0.34	0.29	*	*	0.40	0.92	0.34	*	*
36	0.23	0.17	*	*	0.23	0.69	0.23	*	*
37	0.17	0.17	*	*	0.17	0.40	0.17	*	*
38	0.40	0.23	*	*	0.34	0.52	0.40	*	*
39	0.23	0.23	*	*	0.23	0.34	0.34	*	*
40	0.29	0.23	*	*	0.23	0.46	0.23	*	*
41	0.11	*	*	0.17	0.11	*	0.23	0.17	*
42	0.40	*	*	0.23	0.17	*	0.23	0.17	*
43	0.29	*	*	0.23	0.29	*	0.23	0.23	*
44	0.23	*	*	0.17	0.11	*	0.17	0.17	*
45	0.29	*	*	0.17	0.17	*	0.29	0.23	*
46	0.23	*	*	0.23	0.23	*	0.17	0.17	*
47	0.17	*	*	0.17	0.23	*	0.17	0.17	*
48	0.11	*	*	0.17	0.17	*	0.17	0.23	*
49	0.40	0.11	*	*	*	*	*	*	*
50	0.29	0.23	0.11	*	*	*	0.23	*	*
51	0.34	*	0.23	*	*	*	0.29	*	*
52	0.34	0.17	0.29	*	*	*	0.40	*	*
53	0.23	0.11	0.17	*	*	*	0.17	*	*
54	0.29	0.23	0.23	*	*	*	0.29	*	*
55	0.29	0.23	0.17	*	*	*	0.23	*	*
56	0.29	0.17	0.23	*	*	*	0.23	*	*
57	0.11	*	*	*	*	*	*	*	*
58	0.17	*	0.23	*	0.23	*	0.29	*	*
59	0.23	*	0.17	*	0.34	*	0.40	*	*
60	0.23	*	0.11	*	0.23	*	0.29	*	*
61	0.11	*	*	*	*	*	*	*	*
62	0.17	*	*	*	*	*	*	*	*
63	0.29	*	*	*	*	*	*	*	*

C - Control condition
* - Missing data
TP - Test participant

TABLE 2B

Complete Listing of Smallest Angles Resolved By Test Participants
On the Green Panel for the Control and All Filter Conditions

		Filter							
TP	C	1	2	3	4	5	6	7	8
1	0.17	*	*	0.17	0.23	0.29	*	*	*
2	0.11	*	*	0.06	0.06	0.46	*	*	*
3	0.17	*	*	0.11	0.17	0.29	*	*	*
4	0.23	*	*	0.29	0.29	0.29	*	*	*
5	0.17	*	*	0.11	0.17	0.29	*	*	*
6	0.17	*	*	0.40	0.11	0.46	*	*	*
7	0.23	*	*	0.29	0.23	0.34	*	*	*
8	0.17	0.23	0.17	0.17	*	0.34	*	*	*
9	0.17	0.23	0.11	0.11	*	0.34	*	*	*
10	0.17	0.23	0.23	0.17	*	0.34	*	*	*
11	*	*	0.11	*	*	*	*	*	*
12	*	*	0.40	*	*	*	*	*	*
13	*	*	0.23	*	*	*	*	*	*
14	*	*	0.17	*	*	*	*	*	*
15	*	*	0.11	*	*	*	*	*	*
16	0.11	*	*	0.23	*	*	*	*	0.23
17	0.97	*	*	0.29	*	*	*	*	0.17
18	0.11	*	*	0.17	*	*	*	*	0.23
19	0.17	*	*	0.11	*	*	*	*	*
20	0.11	*	*	0.17	*	*	*	*	*
21	0.17	*	*	0.17	*	*	*	*	*
22	0.17	*	*	0.23	*	*	*	*	*
23	0.11	*	*	0.17	*	*	*	*	*
24	0.11	*	*	0.11	0.11	0.23	*	*	*
25	0.17	0.17	0.17	0.23	*	*	*	*	*
26	0.17	*	*	*	*	0.11	*	*	*
27	0.34	0.34	0.17	0.17	*	*	*	*	*
28	0.11	0.17	0.11	0.17	*	0.17	*	*	*
29	0.23	0.23	0.11	0.23	*	*	*	*	*
30	0.23	0.17	0.17	0.17	*	0.17	*	*	*
31	0.17	0.17	0.17	0.17	*	0.17	*	*	*
32	0.23	0.11	0.11	0.11	*	0.11	*	*	*
33	0.34	0.23	*	*	0.29	0.34	0.23	*	*
34	0.23	0.11	*	*	0.17	0.34	0.23	*	*
35	0.17	0.23	*	*	0.23	0.46	0.23	*	*
36	0.23	0.17	*	*	0.17	0.34	0.17	*	*
37	0.11	0.23	*	*	0.11	0.29	0.23	*	*
38	0.34	0.23	*	*	0.23	0.34	0.23	*	*
39	0.34	0.17	*	*	0.29	0.29	0.23	*	*
40	0.69	0.23	*	*	0.17	0.23	0.23	*	*
41	0.11	*	*	0.11	0.11	*	0.11	0.11	*
42	0.29	*	*	0.17	0.11	*	0.17	0.23	*
43	0.23	*	*	0.17	0.17	*	0.11	0.29	*
44	0.23	*	*	0.11	0.11	*	0.11	0.11	*
45	0.17	*	*	0.11	0.23	*	0.11	0.23	*
46	0.17	*	*	0.11	0.17	*	0.11	0.23	*
47	0.11	*	*	0.11	0.11	*	0.23	0.23	*
48	0.17	*	*	0.11	0.17	*	0.17	0.11	*
49	0.34	0.11	0.11	*	*	*	*	*	*
50	0.17	0.17	0.17	*	*	*	0.17	*	*
51	0.29	*	0.29	*	*	*	0.23	*	*
52	0.46	0.11	0.11	*	*	*	0.29	*	*
53	0.11	0.11	0.17	*	*	*	0.11	*	*
54	0.23	0.17	0.11	*	*	*	0.23	*	*
55	0.17	0.17	0.11	*	*	*	0.23	*	*
56	0.11	0.17	*	*	*	*	0.17	*	*
57	0.17	*	0.17	*	*	*	*	*	*
58	0.17	*	0.17	*	0.17	*	0.23	*	*
59	0.23	*	0.11	*	0.23	*	0.23	*	*
60	0.17	*	*	*	0.17	*	0.17	*	*
61	0.17	*	*	*	*	*	*	*	*
62	0.11	*	*	*	*	*	*	*	*
63	0.23	*	*	*	*	*	*	*	*

C - Control condition
* - Missing data
TP - Test participant

TABLE 18

Complete Listing of Smallest Angles Resolved by Test Participants on the White Panel for the Control and All Filter Conditions

		Filter							
TP	C	1	2	3	4	5	6	7	8
1	0.17	*	*	0.17	0.17	0.23	*	*	*
2	0.06	*	*	0.11	0.11	0.23	*	*	*
3	0.17	*	*	0.17	0.17	0.23	*	*	*
4	0.06	*	*	0.06	0.23	0.17	*	*	*
5	0.11	*	*	0.11	0.17	0.29	*	*	*
6	0.17	*	*	0.17	0.23	0.34	*	*	*
7	0.17	*	*	0.17	0.23	0.29	*	*	*
8	0.11	0.17	0.23	0.17	*	0.34	*	*	*
9	0.17	0.11	0.11	0.11	*	0.17	*	*	*
10	0.11	0.23	0.23	0.11	*	0.23	*	*	*
11	*	*	0.11	*	*	*	*	*	*
12	*	*	0.23	*	*	*	*	*	*
13	*	*	0.06	*	*	*	*	*	*
14	*	*	0.11	*	*	*	*	*	*
15	*	*	0.11	*	*	*	*	*	*
16	0.11	*	*	0.11	*	*	*	*	0.17
17	0.29	*	*	0.23	*	*	*	*	0.17
18	0.11	*	*	0.17	*	*	*	*	0.29
19	0.11	*	*	0.11	*	*	*	*	*
20	0.11	*	*	0.11	*	*	*	*	*
21	0.11	*	*	0.11	*	*	*	*	*
22	0.11	*	*	0.17	*	*	*	*	*
23	0.11	*	*	0.17	*	*	*	*	*
24	0.17	*	*	0.11	0.11	0.23	*	*	*
25	0.17	0.17	0.17	0.17	*	*	*	*	*
26	0.29	*	*	*	*	0.17	*	*	*
27	0.23	0.23	0.23	0.17	*	*	*	*	*
28	0.17	0.17	0.17	0.17	*	0.17	*	*	*
29	0.17	0.17	0.17	0.17	*	*	*	*	*
30	0.17	0.17	0.17	0.17	*	0.17	*	*	*
31	0.17	0.17	0.17	0.17	*	0.17	*	*	*
32	0.17	0.17	0.17	0.11	*	0.17	*	*	*
33	0.23	0.17	*	*	0.23	0.23	0.23	*	*
34	0.23	0.11	*	*	0.17	0.17	0.23	*	*
35	0.23	0.23	*	*	0.23	0.17	0.23	*	*
36	0.17	0.23	*	*	0.17	0.23	0.17	*	*
37	0.11	0.17	*	*	0.11	0.11	0.11	*	*
38	0.17	0.29	*	*	0.11	0.23	0.17	*	*
39	0.17	0.17	*	*	0.17	0.29	0.17	*	*
40	0.29	0.11	*	*	0.23	0.17	0.11	*	*
41	0.17	*	*	0.11	0.11	*	0.11	0.11	*
42	0.23	*	*	0.17	0.23	*	0.11	0.17	*
43	0.17	*	*	0.17	0.23	*	0.11	0.17	*
44	0.17	*	*	0.17	0.11	*	0.11	0.17	*
45	0.17	*	*	0.17	0.11	*	0.11	0.11	*
46	0.23	*	*	0.23	0.11	*	0.11	0.29	*
47	0.11	*	*	0.11	0.17	*	0.11	0.17	*
48	0.11	*	*	0.11	0.11	*	0.11	0.11	*
49	0.17	0.11	*	*	*	*	*	*	*
50	0.11	0.11	0.11	*	*	*	0.11	*	*
51	0.23	*	0.17	*	*	*	0.11	*	*
52	0.69	0.11	0.23	*	*	*	0.11	*	*
53	0.17	0.11	0.11	*	*	*	0.11	*	*
54	0.29	0.17	0.17	*	*	*	0.11	*	*
55	0.11	0.17	0.11	*	*	*	0.17	*	*
56	0.17	0.11	0.11	*	*	*	0.11	*	*
57	0.23	*	*	*	*	*	*	*	*
58	0.17	*	0.23	*	0.17	*	0.17	*	*
59	0.23	*	0.23	*	0.17	*	0.17	*	*
60	0.11	*	0.11	*	0.17	*	0.17	*	*
61	0.11	*	*	*	*	*	*	*	*
62	0.11	*	*	*	*	*	*	*	*
63	0.17	*	*	*	*	*	*	*	*

C - Control condition
* - Missing data
TP - Test participant

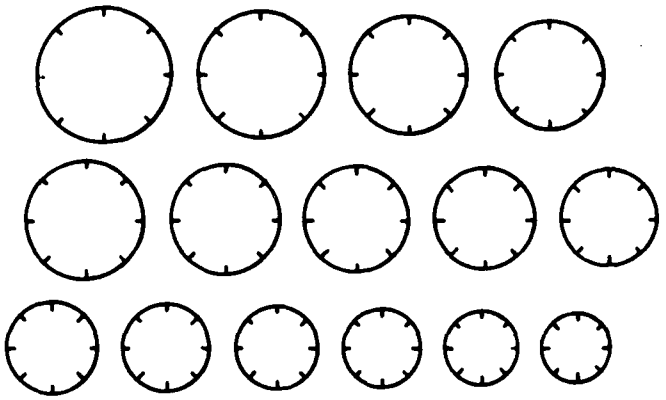
APPENDIX B

COMPLETE DATA LISTING

SAMPLE DATA FORM

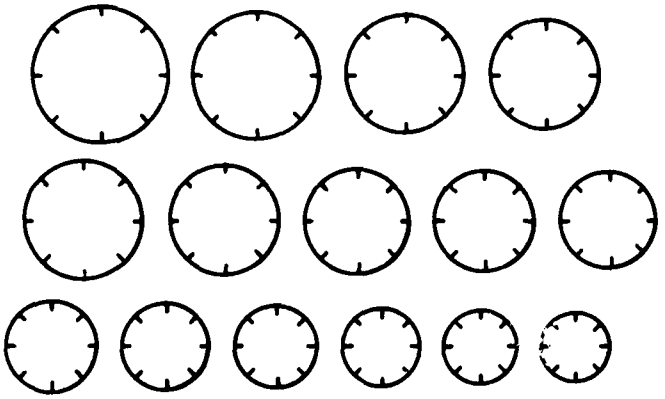
NAME _____ DATE _____ TIME _____

WHITE



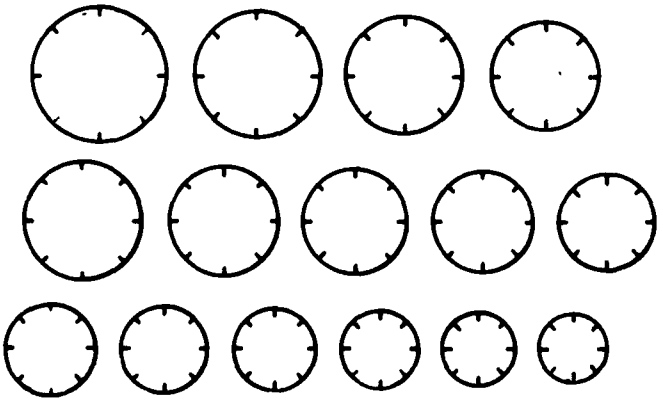
COMMENTS:

GREEN



COMMENTS:

O D



COMMENTS:

APPENDIX A

SAMPLE DATA FORM

REFERENCES

1. Barnes, J.A. (1969). Contrast handbook for Federal Standard 595 colors (Technical Note 1-69). Aberdeen Proving Ground, MD: US Army Human Engineering Laboratory.

2. Cook, J.N., & Johnson, J.R. (1983). Customer test for laser protective device (U). (TRADOC TRMS No. 2-000308). Fort Knox, KY: US Army Armor and Engineer Board.

3. Chapanis, A., Garner, W.R., & Morgan, C.T. (1957). Applied experimental psychology. New York: John Wiley & Sons, Inc.

4. Graham, H.C. (Ed.). (1965). Vision and visual perception. New York: John Wiley & Sons, Inc.

5. Richardson, F.S. (1968). Target acquisition by ground observers--A physical interpretation. Fort Ord, CA: US Army Combat Developments Experimentation Command.

4. If different categories of test participants are used, e.g., TOW and tank gunners, maintain their classification throughout all testing phases.

5. Consider the possibility of using lower contrast figures which would be closer to the contrast representative of tactical targets. Contrasts of .01 to .03 should be considered and included.

CONCLUSIONS

The modified Landolt C-ring test, as devised by HEL, seems to be able to evaluate the effect of various laser filters on soldiers' visual acuity.

The preliminary indication is that the modified Landolt C-ring test may be a viable test to help prescreen filters. The filters that caused changes in visual acuity in the C-ring test were also among those filters that caused changes in gunner performance, but there was not a perfect match of filters causing a change in gunner performance during the Fort Knox test and this test. Also, the direction of the change in performance was different in the two tests. Test participants showed a degradation in their performance when some of the filters were included in the system sights during the Fort Knox test. However, the same test participants showed an improvement in visual acuity when they viewed the test panels through some of the same filters during this test. Perhaps more studies are needed to fully develop and refine the predictive relationship between the C-ring test and field performance.

RECOMMENDATIONS

The possibility of developing such a combined visual test, based on acuity, target color, and target contrast, should be investigated further. Although the test is easy to construct and administer, more expert advice and recommendations should be sought when choosing the colors used for the panels and the C-rings.

If any follow-on testing is done to determine the efficacy of filters and the predictive capability of the modified C-ring test, the following recommendations are made:

1. Include filters with high optical density values: values of six and higher should be considered.

2. Attempt to do some testing under other than ideal outdoor conditions. Include testing when it is overcast, make use of shade, and include testing during dusk and dawn. Less than optimal light conditions may cause the effects of various filters to become more pronounced. This test may also be used indoors where the lighting is more easily controlled, constant, and reproducible; however, consideration must be given to the color characteristics of the lights used.

3. When constructing the test range, ensure that the perceived incremental difference from C-ring to C-ring is as small as possible, well under 0.5 minutes of arc. For example, 0.1 would be a convenient acceptable increment. Remember that if a viewing optic is to be used, multiplying the actual visual angle by the power of the viewing optic will give a good approximation of the angle perceived by the test participants.

The only case in which the interaction between contrast ratio and filter (viewing condition) was significant was for filter 5.

DISCUSSION

The primary comparison that can be drawn from Table 1 is that as the target contrast ratio decreased, from black-white (0.78) to OD-green (0.43) to black-OD (0.23), the mean visual angle that the test participants could resolve increased for the control as well as for all the filter cases.

Table 2 shows the smallest mean visual angle resolved by the test participants in the filter conditions tended to be the same or smaller than the angles resolved in the control condition. For the filter viewing conditions, the smallest resolved mean visual angles were the same or smaller in 75 percent of the cases on the white panel, 87.5 percent of the cases on the green panel, and 62.5 percent of the cases on the OD panel. This may suggest that the filters acted to reduce glare as would a pair of regular sunglasses and did not degrade the visual acuity of the test participants, but rather tended to enhance their visual performance.

The large degradation of the visual acuity caused by filter 5 against the OD panel is an interesting phenomenon. The actual cause is not known, but the significance of the interaction between filter and contrast (indicated only for filter 5 in Table 3), suggests that this filter has some optical characteristics which could explain the phenomenon. Obtaining a complete explanation would require detailed spectral analysis of the paints and the filter, which is beyond the scope of this effort.

A summary of the results obtained in the Fort Knox test is given in Appendix D and can be used to compare the filters' effect on the performance of the gunners in the field to the performance of the gunners in this test. Briefly during the Fort Knox test, filters 1, 2, 4, and 5 changed tank gunners' performance so that the gunners tended to require more time to detect the targets, detection probability tended to be lower, and the calculated circular error at trigger pull was larger. These decrements were also characteristic of the changes in TOW gunner performance caused by filters 1, 2, 3, 4, 5, and 6 during daylight.

In the Fort Knox test, selected filters (1, 2, and 4) were used in an evaluation of gunner performance during dawn and dusk. Although no dawn or dusk testing was done during this effort, the dawn-dusk results from the Fort Knox test are included. During the dawn tests, filter 1 changed tank gunner performance so that the gunners required more time to detect the targets. During the dusk phase, the gunner's target detection probability was lower for all three selected filters. None of the selected filters changed TOW gunner performance during the dawn and dusk phases of the Fort Knox test. Summarizing the results of this effort, the modified Landolt C-ring test identified filters 1, 2, 3, and 5 as those that changed gunner performance. The Fort Knox test identified filters 1, 2, 4, and 5 as those that changed tank gunner performance, and filters 1, 2, 3, 4, 5, and 6 as those that changed TOW gunner performance.

Each control and filter combination was treated as an independent data pair set and a two-factor, within-subject analysis of variance (ANOVA) was performed. The summation of the ANOVA results is presented in Table 3, with the individual ANOVAs presented in Appendix C, Tables 1C through 8C. The last viewing condition, filter 8 with three test participants, has been excluded from Table 3 and any further consideration because of the small sample size. (The ANOVA results for filter 8 are included in Appendix C.) Since there were many tests to be performed on the data, the F-ratios were tested at the .01 level.

TABLE 3

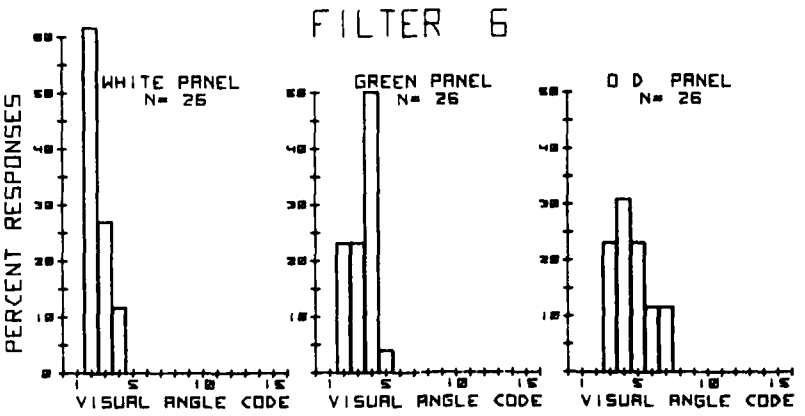
Summation of the Results of the ANOVA Calculations
Indicating Significance at the 0.01 Level

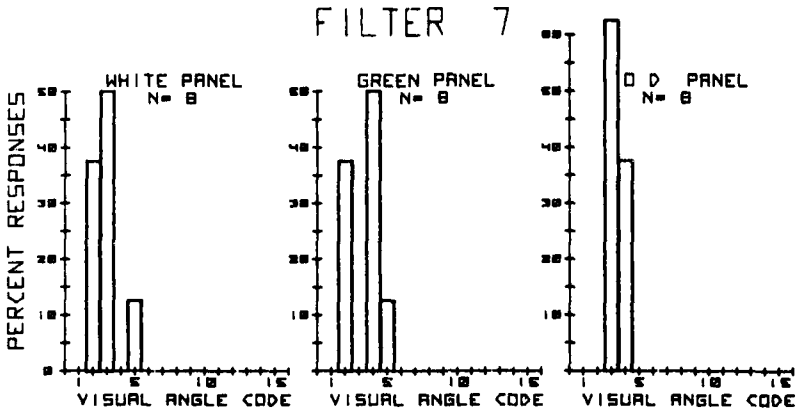
	Filter						
	1	2	3	4	5	6	7
Contrast	P<.01	n.s.	P<.01	P<.01	P<.01	P<.01	P<.01
V Cond	P<.01	P<.01	P<.01	n.s.	P<.01	n.s.	n.s.
Contrast x V Cond	n.s.	n.s.	n.s.	n.s.	P<.01	n.s.	n.s.

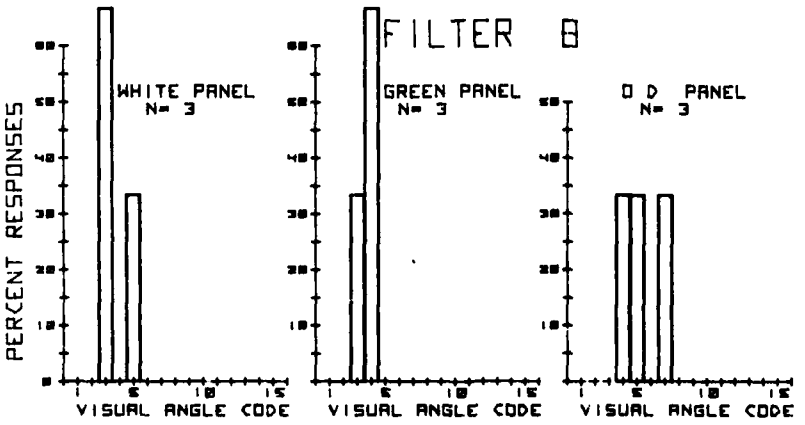
V Cond = Viewing condition (filters)
n.s. = Not significant
P = Probability

The contrast ratio of the C-rings was a significant factor reducing visual acuity for all viewing conditions except filter 2. A reduction in visual acuity is indicated by increases in the smallest visual angles that an observer can resolve.

Changes in test participants' visual acuity were significantly influenced by filters (viewing conditions) 1, 2, 3, and 5 when compared to the visual acuity exhibited by the test participants under the control (no filter) condition. The increases, indicated by smaller angles resolved, in visual acuity under conditions 1, 2, and 3, when compared to the corresponding control condition, are significant. The decrease, indicated by larger angles required for perception, is significant for filter 5. The minimum visual angle required for perception with filter 5 was 108 percent of the visual angle required by the test participants under the control condition on the OD panel; the change in performance against the white and green panels, however, showed increases of only 29 and 32 percent, respectively.

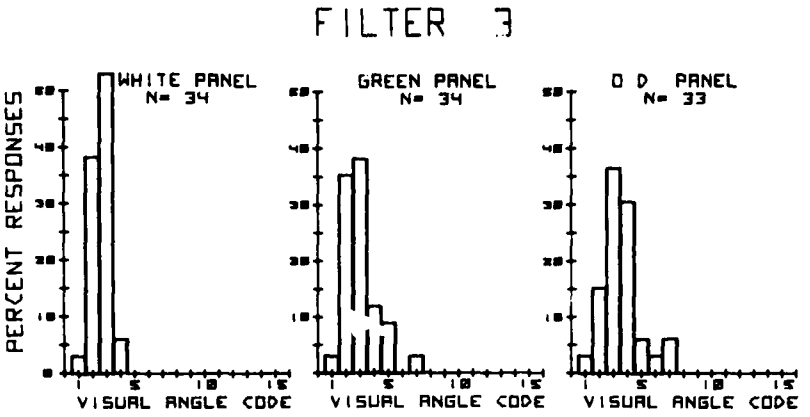


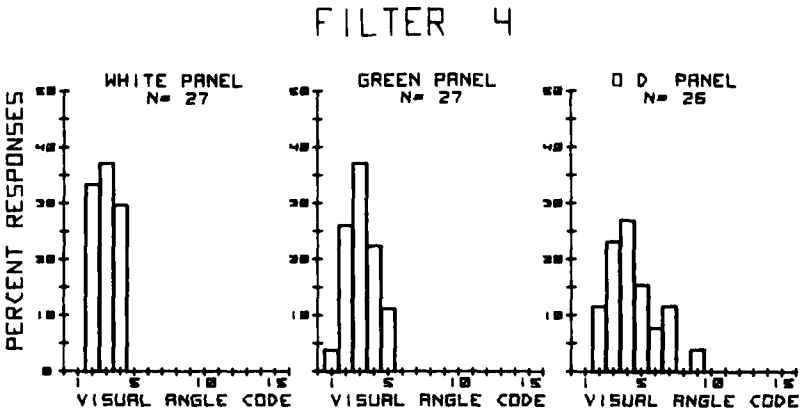


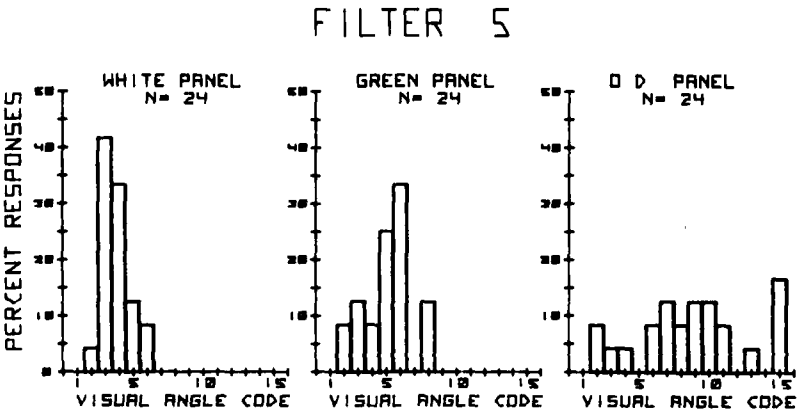


CODE	ARC-MIN	CODE	ARC-MIN
1	0.06	9	0.52
2	0.11	10	0.57
3	0.17	11	0.69
4	0.23	12	0.74
5	0.29	13	0.80
6	0.34	14	0.87
7	0.40	15	0.92
8	0.46		

Figure 4. Smallest angles resolved by test participants for the filter 6, filter 7, and filter 8 conditions on each panel.

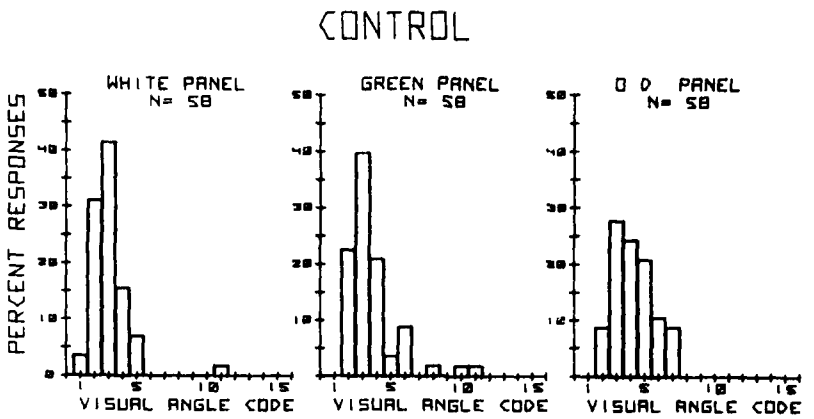


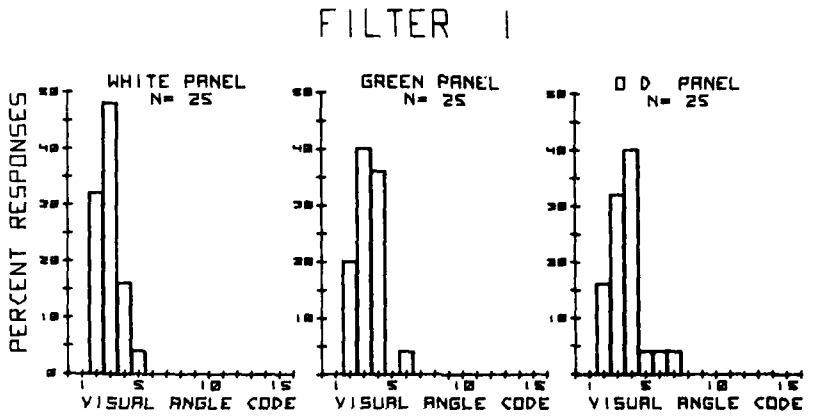


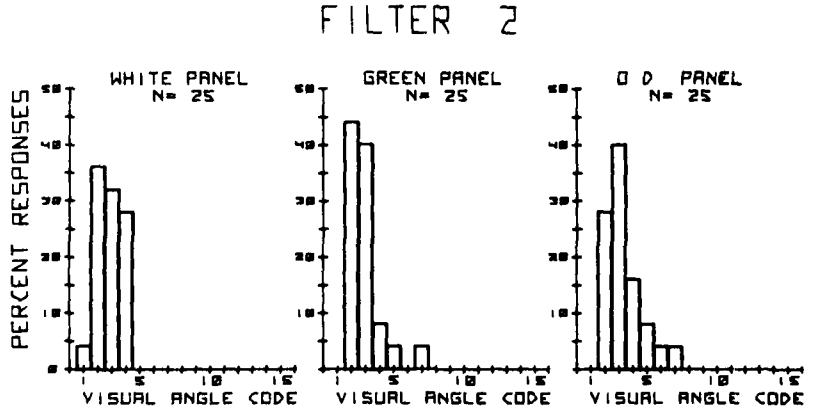


CODE	ARC-MIN	CODE	ARC-MIN
1	0.06	9	0.52
2	0.11	10	0.57
3	0.17	11	0.69
4	0.23	12	0.74
5	0.29	13	0.80
6	0.34	14	0.87
7	0.40	15	0.92
8	0.46		

Figure 3. Smallest angles resolved by test participants for the filter 3, filter 4, and filter 5 conditions on each panel.







CODE	ARC-MIN	CODE	ARC-MIN
1	0.06	9	0.52
2	0.11	10	0.57
3	0.17	11	0.69
4	0.23	12	0.74
5	0.29	13	0.80
6	0.34	14	0.87
7	0.40	15	0.92
8	0.46		

Figure 2. Smallest angles resolved by test participants for the control, filter 1, and filter 2 conditions on each panel.

APPENDIX C

ANALYSIS OF VARIANCE TABLES

TABLE 1C

Analysis of Variance Summation for Filter 1

	SS	df	MS	F	
TPs	0.3041	24	0.01267		
Contrast (Panel Color)	0.0890	2	0.0445	6.98	P<.01
TPs By Contrast	0.3062	48	0.0064		
Viewing (Filter or None)	0.1061	1	0.1061	8.08	P<.01
Viewing By TPs	0.3152	24	0.0131		
Viewing By Contrast	0.0097	2	0.0048	1.19	n.s.
Viewing By Contrast By TPs	0.1951	48	0.0041		
Total	1.3254	144	0.00920		

TPs - Test participants
n.s. - Not significant

TABLE 2C

Analysis of Variance Summation for Filter 2

	SS	df	MS	F	
TPs	0.2439	17	0.01435		
Contrast (Panel Color)	0.0346	2	0.0173	4.19	n.s.
TPs By Contrast	0.1401	34	0.0041		
Viewing (Filter or None)	0.0817	1	0.0817	10.47	P<.01
Viewing By TPs	0.1327	17	0.0078		
Viewing By Contrast	0.0138	2	0.0069	1.77	n.s.
Viewing By Contrast By TPs	0.1324	34	0.0039		
Total	0.7791	102	0.00764		

TPs - Test participants
n.s. - Not significant

TABLE 3C

Analysis of Variance Summation for Filter 3

	SS	df	MS	F	
TPs	0.3890	32	0.01216		
Contrast (Panel Color)	0.1316	2	0.0658	18.96	P<.01
TPs By Contrast	0.2221	64	0.0035		
Viewing (Filter or None)	0.0126	1	0.0126	3.61	n.s.
Viewing By TPs	0.1118	32	0.0035		
Viewing By Contrast	0.0038	2	0.0019	0.64	n.s.
Viewing By Contrast By TPs	0.1924	64	0.0030		
Total	1.0633	192	0.00554		

TPs - Test participants
n.s. - Not significant

TABLE 4C

Analysis of Variance Summation for Filter 4

	SS	df	MS	F	
TPs	0.4258	25	0.01703		
Contrast (Panel Color)	0.1570	2	0.0758	17.72	P<.01
TPs By Contrast	0.2216	50	0.0044		
Viewing (Filter or None)	0.0071	1	0.0071	1.15	n.s.
Viewing By TPs	0.1539	25	0.0062		
Viewing By Contrast	0.0201	2	0.0101	2.88	n.s.
Viewing By Contrast By TPs	0.1747	50	0.0035		
Total	1.1603	150	0.00774		

TPs - Test participants
n.s. - Not significant

TABLE 5C

Analysis of Variance Summation for Filter 5

	SS	df	MS	F	
TPs	0.6565	23	0.02854		
Contrast (Panel Color)	0.9292	2	0.4646	34.13	P<.01
TPs By Contrast	0.6262	46	0.0136		
Viewing (Filter or None)	0.6347	1	0.6347	26.20	P<.01
Viewing By TPs	0.5571	23	0.0242		
Viewing By Contrast	0.3684	2	0 1842	18.52	P<.01
Viewing By Contrast By TPs	0.4575	46	0.0099		
Total	4.2295	138	0.03065		

TPs - Test participants
n.s. - Not significant

TABLE 6C

Analysis of Variance Summation for Filter 6

	SS	df	MS	F	
TPs	0.5106	25	0.02042		
Contrast (Panel Color)	0.2131	2	0.1065	28.29	P<.01
TPs By Contrast	0.1883	50	0.0038		
Viewing (Filter or None)	0.0440	1	0.0440	5.00	n.s.
Viewing By TPs	0.2200	25	0.0088		
Viewing By Contrast	0.0277	2	0.0139	3.25	n.s.
Viewing By Contrast By TPs	0.2132	50	0.0043		
Total	1.4169	150	0.00945		

TPs - Test participants
n.s. - Not significant

TABLE 7C

Analysis of Variance Summation for Filter 7

	SS	df	MS	F	
TPs	0.0785	7	0.01122		
Contrast (Panel Color)	0.0158	2	0.0079	3.79	n.s.
TPs By Contrast	0.0291	14	0.0021		
Viewing (Filter or None)	0.0018	1	0.0018	0.39	n.s.
Viewing By TPs	0.0313	7	0.0045		
Viewing By Contrast	0.0040	2	0.0020	0.73	n.s.
Viewing By Contrast By TPs	0.0381	14	0.0027		
Total	0.1984	42	0.00472		

TPs - Test participants
n.s. - Not significant

TABLE 8C

Analysis of Variance Summation for Filter 8

	SS	df	MS	F	
TPs	0.0422	2	0.02112		
Contrast (Panel Color)	0.0146	2	0.0073	0.98	n.s.
TPs By Contrast	0.0297	4	0.0074		
Viewing (Filter or None)	0.0035	1	0.0035	0.08	n.s.
Viewing By TPs	0.0912	2	0.0456		
Viewing By Contrast	0.0172	2	0.0086	0.96	n.s.
Viewing By Contrast By TPs	0.0360	4	0.0090		
Total	0.2345	12	0.01954		

TPs - Test participants
n.s. - Not significant

APPENDIX D

SUMMARY OF FORT KNOX TEST RESULTS

SUMMARY OF FORT KNOX TEST RESULTS

INTRODUCTION

During the main test (Cook & Johnson, 1983), three TOWs and five tanks were located on a hill and the gunners were required to engage targets in the valley. The vehicles used as targets were two M60 tanks, two armored personnel carriers with TOW, and two 5-ton trucks. The targets presented a stationary array with no more than two targets at nominal slant ranges of 900, 1,600, and 2,000 m. The participants were not allowed to watch as the targets maneuvered into their positions.

The measures used to evaluate test participants' performance during the main test were: time to detect targets, percentage (probability) of targets detected, target identification, and calculated circular radial error (CRE) at the time the test participant simulated firing. The participants were also asked to compare the brightness of the sights they were using (with and without filters) in this test to the brightness of the sights they normally used in their units.

During the main test, one of the filters was tested in two configurations. Filter 1 was provided as a clip-on sample and also incorporated inside an M32 tank sight as an integral part of the sight.

The filters are referred to by the same code numbers used in the main body of the report. The intent here is not to summarize the influence of the specific materials on gunner performance, but to present a field reference on how well the modified Landolt C-ring test predicted changes in gunner performance.

RESULTS

In the main test, the results were presented separately for tank and TOW gunners. Thus the results are separated here, even though the distinction was not made during the testing described in the main body of the report (see Tables 1D and 2D).

TABLE 1D

Statistically Significant Results for Tank Gunners

Test Conditions	Filter	Results
Daylight		Test participants correctly identified the targets at least 99 percent of the time under all conditions.
	Control	Test participants reported that the sight was "slightly brighter" under this condition than the sight they normally used.
	1	When used as a clip-on, test participants required more time to detect targets at 1,600 and 2,000 m. Test participants rated the sight as "quite a bit brighter" under this condition than the sight they normally used. When this filter was incorporated into the M32 sight, test participants required more time to detect targets at all ranges. Target detection probability was lower at 1,600 and 2,000 m. Test participants rated the sight as "slightly dimmer" under this condition than the sight they normally used.
	2	Test participants required more time to detect targets at all ranges. The calculated CRE was larger. Test participants said that the sight was "slightly dimmer" under this condition than the sight they normally used.
	3	There were no significant differences. Test participants were not asked to rate the brightness of this sight with this filter.
	4	Test participants required more time to detect targets at all ranges. Target detection probability was lower at 1,600 m. Test participants reported the sight to be "slightly dimmer" under this condition than the sight they normally used.
	5	Test participants required more time to detect targets at 1,600 and 2,000 m. Target detection probability was lower. Test participants were not asked to rate the brightness of the sight with this filter.
	6	No significant differences were found. The test participants were not asked to rate the brightness of the sight with this filter.
	7	No significant differences were found. The test participants were not asked to rate the brightness of the sight with this filter.
	8	No significant differences were found. The test participants were not asked to rate the brightness of the sight with this filter.
Dawn and Dusk (Only the control and filters 1, 2, and 4 were used during this phase)		
		The test participants were not asked to rate the brightness of the sight during these phases of testing.
Dawn	1	When the filter was used as a clip-on, test participants required more time to detect the targets. When this filter was integrated into the M32 sight, no significant differences were found.
	2,4	No significant differences were found.
Dusk		
	1	When this filter was used as a clip-on, no significant differences were found. When this filter was integrated into the M32 sight, target detection probabilities were lower.
	2	Target detection probability was lower.
	4	Target detection probability was lower.

TABLE 2D

Statistically Significant Results for TOW Gunners

Test Conditions	Filter	Results
Daylight		Test participants correctly identified the targets at least 99 percent of the time under all conditions.
		Under all filter conditions, test participants rated the brightness of the sight to be "about the same" as the brightness of the sights they normally used.
	1	Test participants required more time to detect targets.
	2	Test participants required more time to detect targets. Target detection probability was lower. The CRE was larger.
	3	The calculated circular error was larger.
	4	Test participants required more time to detect targets. The calculated circular error was larger.
	5	Test participants required more time to detect the target. Target detection probability was higher.
	6	Target detection probability was higher.
	7	No significant differences were found.
	8	No significant differences were found.
Dawn and Dusk (Only filters 1, 2, and 4 were used in this testing.)		
		No significant differences were found for these filter conditions during these phases of testing.

END

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